Remote Diagnostic Protocol and System for U-Car

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Abstract. This paper proposes a remote diagnostic protocol and system for U-Car, which has same functionality of conventional scanners, automobile diagnostic instruments. It consists of a remote server, mobile handsets with an application and a connecting device. The remote server has vehicle diagnostic database. The application program on mobile handsets relays diagnostic signals and controls the flow of data packets based on the dedicated protocol. The connecting device is used for converting the signal level and protocols between automobiles and handsets. Since the remote server diagnoses vehicle directly, diagnostic history can be accumulated automatically. Therefore, value added services such as connecting service-shop directly based on diagnostic results are possible. New automobile systems can be easily dealt only by changing diagnostic database of the remote server. Although the proposed system is constructed based on mobile handsets, it can be easily extended to car-PCs and other systems for U-car.

Keywords: U-car, Telemetry, Vehicle diagnostic system, Mobile handsets.

1 Introduction

With the advance of communication technologies, automobile systems become more and more intelligent. U-car means such intelligent car systems based on network capability. Many value-added services such as navigation services based on real-time traffic information, car office based on car-PCs, and automated highway system can be possible from network capability using various media. Among these, mobile handsets are important and powerful media.

Telemetry services are remote control and measurement services. Users can control local devices remotely using mobile handsets that connect to remote

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control servers, which are physically connected to the controlled devices. Meanwhile, different from this common concept of telemetry services, the concept of Smart Telemetry Service(STS)[1] has been proposed. In STS, the local device is controlled from the remote server by physically connecting with mobile handsets, which is easy-to-carry and hence very important media in the ubiquitous environment.

Vehicle Diagnostic system is one of the important part in U-car systems. In automobile diagnosis market, the functionality of conventional scanner are imported to telematics devices that are customized for each type of car systems. Although new car systems accord to the international standard ODB-II, there are many previous car systems using other protocols. Therefore, it is difficult to make telematics devices that accommodate these various car systems.

In this paper, we propose a diagnostic protocol and system for U-car. The proposed system is based on Smart Telemetry Service technology and uses remote server, simple connecting devices(or converting board), and wireless handsets. It is possible to cover various car systems by downloading an application on mobile handsets and upgrading the server.

Moreover, to resolve time delay problem in mobile networks, a dedicated protocol is designed for vehicle diagnostic systems. In the proposed method, vehicle diagnostic operation is executed directly from remote server. Additional car system can be covered by only upgrading diagnostic database on the server. Various services can easily be deployed based on the diagnostic history accumulated automatically in the server.

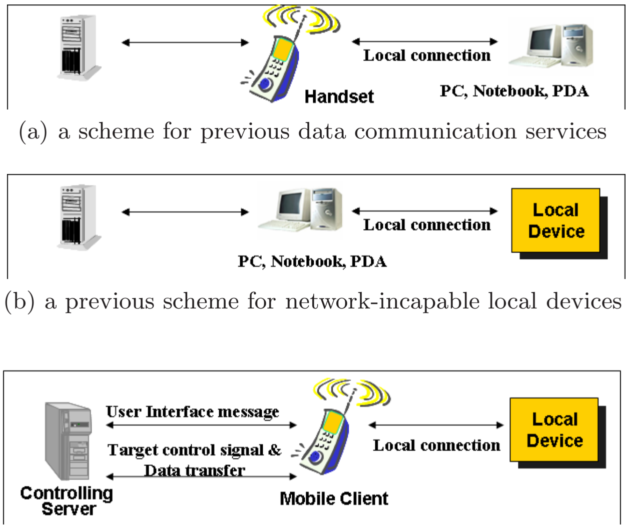
This paper is organized as follows. At first, we explain the concept of Smart Telemetry Services and the configuration of remote diagnostic systems. Then the problem of time delay is discussed and the dedicated protocol to resolve this problem is explained briefly. To show the effectiveness of the proposed method, experimental results are shown. Finally, future works are discussed.

2 Smart Telemetry Services

Different from general telemetry services, Smart Telemetry Service(STS) is based on the mobile handsets carried by users. STS makes remote server control local devices directly which do not have network capability. That is, it requires users to carry mobile handsets or other devices with network capability. It is useful in the cases when most operations can be executed in the remote server without changing local devices.

It is also different from the previous data communication scheme that uses mobile handsets as simple CDMA modem. The difference of previous scheme and the proposed method is depicted in Fig.1.

Fig.1 (a) shows the previous data communication scheme. In this scheme, notebook or PDA systems connect to remote server by using mobile handsets as CDMA modem. In this case, it can be applicable only for network-capable devices such as notebook or PDA. That is, it cannot be applicable for the previous network-incapable local devices.



(a) a scheme for previous data communication services

(b) a previous scheme for network-incapable local devices

(c) the proposed scheme

Fig. 1. Comparison between previous schemes and the proposed scheme

Fig.1 (b) shows a typical scheme controlling these network-incapable local devices. In this scheme, using notebook or PDA, local devices can connect to remote server through wired or wireless network. Recently, market trend goes to converge mobile handsets and PDA. However, due to time and cost, it is not appropriate for common users.

Fig. 1 (c) shows the proposed scheme that remote server controls local devices through mobile handsets. In this case, mobile handset operates as a virtual cable interconnecting local devices and remote server over CDMA networks.

The proposed scheme is effective for controlling previous network-incapable local devices from remote server. It is done by downloading application for mobile handsets.

In this scheme, one of the important problem is the time-delay in wireless networks and internet. For most vehicle diagnostic protocols including ODB(On-Board Diagnostics)-II, it is required to exchange signals within pre-defined time for establishing connection and for keeping connection after connection establishment. Since such conditions cannot be guaranteed in wireless networks, it is necessary to design a dedicated protocol that resolves this time-delay problem.

3 Configuration of the Proposed Vehicle Diagnostic System

In Fig.2, the configuration of the proposed vehicle diagnostic system is depicted. The remote server and the application on mobile handsets exchange information

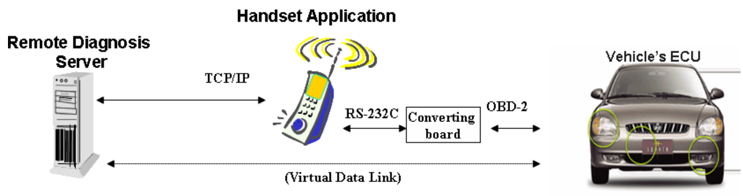


Fig. 2. Configuration of the proposed vehicle diagnostic system

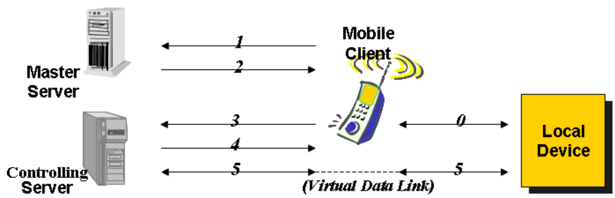


Fig. 3. Procedure of the proposed vehicle diagnostic systems

on TCP/IP. Mobile handset application does the functionality of user interface and relaying data for remote diagnostic operations to ECUs(Engine Control Units) through the converting board. Mobile handsets and the converting board are connected through UART with voltage level of 0 to 3.3[V] and the converting board changes voltage levels and communication schemes for the ODB-II protocol or others.

Users can select automatic diagnostic operation for pre-registered car system or do manual diagnostic operation for other car systems using user interface menus provided by the remote server. After selecting the type of car system and connecting the cable between the converting board and ECUs, users can start diagnostic operation. According to the protocol between mobile handsets application and the remote server, the control data from the remote server bypasses to ECUs through the converting board that converts signal levels and communication schemes.

Through the pre-defined establishment sequence and the diagnostic protocol, ECUs and the remote server exchange data for diagnostic operation. Then, the remote server analyzes the diagnostic data. Finally, users can check the results through mobile handsets. Such results are saved automatically on remote server and various additional services such as automatically connecting to nearby service shops can be provided easily based on the results.

In this paper, we concentrate on the parts of Diagnostic Trouble Codes(DTC) and MIL (Malfunction Indicator Light) codes which are frequently used for commercial stand-alone scanner. Although commercial stand-alone scanner has additional functionality like analog signal measurements, this functionality is rarely used. For the proposed cost-effective diagnostic system, we have no choice but to consider only the parts with digital signals.

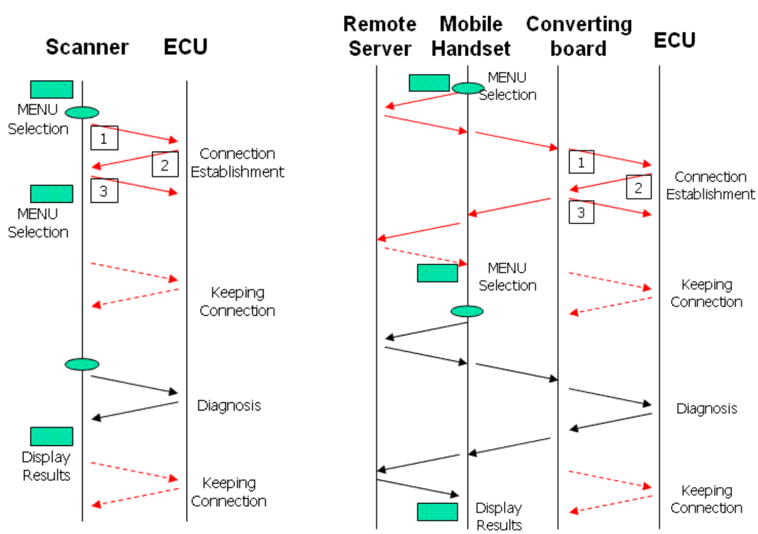
Fig.3 shows the procedure of the proposed system briefly. The procedure can be summarized as follows:

- Step 0: The handset and ECUs of the automobile are connected using a converting board.
- Step 1 and Step 2: The handset sends the service request signal to master server.
- Step 3 and Step 4: ECUs of the automobile (local device) is connected to the controlling server through the wireless handset.
- Step 5: Using virtual data link, data is transmitted and analyzed. After that, the results are displayed in the handset.

Note that the functionality of Master Server and Controlling Server in Fig. 3 can be located together in one remote server or can be distributed on more than two servers with load-balancing capability.

4 A Protocol for Resolving Time-Delay Problem

To illustrate the basic concept of the protocol for resolving time-delay problem in wireless networks, exchange of diagnostic data is depicted in Fig.4. Here, square parts represent messages for users from the stand-alone scanner(or the remote server) and elliptic parts represent the key input of users to the scanner(or mobile handsets). Arrow lines represent data flow between the scanner(or mobile handsets through the converting board) and ECUs.



(a) Communication sequence between the scanner and ECUs (b) Communication sequence for the proposed system

Fig. 4. Communication sequence of data for diagnostic operation

Command	Length	Baudrate Setting	Config. 1	Config. 2	Config. 3	Config. 4	Checksum
33H	12	8 bytes	1 byte	1 byte	1 byte	1 byte	1 byte

(a) Data format of Configuration Command

Command	Length	Initialization configuration	Data	Checksum
35H	n	1 byte	(n-1) bytes	1 byte

(b) Data format of Communication Setup Command

5 bps Code	1st ECU Response	Min. Delay for Response	1st Board Response
1 byte	n bytes (n=0,1,2,3)	1 byte	1 byte

(c) Data format of Data field in (b) (5 bps)

No. of Random Pattern Data	Random Pattern Data	1st ECU Response	Min. Delay for Response	1st Board Response
Nr	Nr bytes	n bytes (n=0,1,2,3)	1 byte	1 byte

(d) Data format of Data field in (b) (random pattern)

Fig. 5. Data format of the dedicated protocol

There are several timing requirements in the protocol between the scanner and ECUs. Typical examples are related to the connection establishment and keeping connection. When the scanner sends signal 1 to the ECU for connection establishment, the ECU responses signal 2 within pre-defined time to notify ready condition. In this case, the scanner should send signal 3 within a certain amount of time. However, if the remote server checks signal 2 and sends signal 3, such timing requirements cannot be satisfied. It is due to the unpredictable time-delay in wireless networks and internet.

To resolve this problem, we design a dedicated protocol that manipulates local response. Using this protocol, the application program on mobile handsets generates local response directly while sending response to the remote server. Therefore, timing requirement of the vehicle diagnostic protocol can be satisfied while notifying server that connection is successfully established.

After connection establishment, it is also necessary to send connection keeping signal within pre-defined time to make connection alive. If remote server sends directly these signals for keeping connection, due to the unpredictable time-delay in wireless networks and internet, it is impossible to guarantee timing requirement for keeping signal. Moreover, unnecessary data exchange on wireless network results in the increase of the cost for data communication. With the dedicated protocol for keeping connection, the application program on mobile handsets can generate these signals periodically after first receiving command related to this operation. Therefore, we can satisfy timing requirement for keeping connection and also reduce unnecessary data exchange through wireless networks.

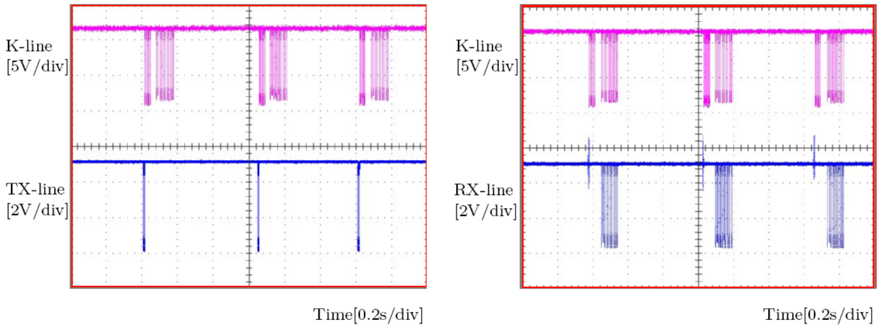
To show the details of the dedicated protocol, we depicted data format of the commands for the converting board in Fig 5. Using configuration command of Fig. 5(a), we can change baudrate and polarity, synchronization method, channel selection, pull-up selection, and handshaking method to support various car systems. Fig. 5(b) shows communication setup command that is used for establishing command. It selects initialization method of 5 bps mode and wakeup pattern generation mode which generates 50ms wakeup patterns. initialization configuration contains the length of 1st ECU response data and the length of 1st acknowledgement data. If initialization method is 5 bps mode, data fields in Fig. 5(b) is in the form of Fig. 5(c). For random pattern mode case(wakeup pattern generation mode), it is in the form of Fig.5(d). In both cases, data fields in Fig. 5(b) contains the value of initialization code, 1st ECU response data, minimum delay for response time, and 1st acknowledgement data. After checking with this 1st ECU response data, converting board sends 1st acknowledgement data to ECU after minimum delay for response time.

5 Experimental Results

To show the applicability of the proposed system, we construct a diagnostic program for remote server, an application program for mobile handsets and a converting board respectively. In constructing database on the remote server for vehicle diagnostics and the hardware/software systems for the converting board, we cooperated with Nex-tek Cooperation, one of the major makers of commercial stand-alone scanners[5].

A diagnostic program for the remote server works together with multi-process/ multi-thread TCP/IP server module and database for vehicle diagnosis. An application program on mobile handsets is implemented on BREW environment[6]. LCD display and keypad of mobile handsets act like dummy terminal through which users can select type of car systems or desired diagnostic operation. They can also be used for checking the results of diagnostic operation. 8-bit micro-controller (PIC16C73 of Microchips Co.) is used for the converting board. The program of the converting board is coded in assembly language to enhance real-time performance. For serial communication between the converting board and mobile handsets, internal serial ports are used. On the other hand, a software-generated serial communication scheme through digital input/output pins is used for communication between the converting board and ECUs. As mentioned above, schemes in the commercial system is referenced in designing hardware of the converting board for signal level conversion and output pattern selection for various car systems.

Fig. 6 shows the waveforms of diagnostic operation. the ECU of ATOS (Hyundai Motor Company)[7] is diagnosed. The upper waveforms of (a) and (b) show signal on K-line through which the converting board and the ECU communicate diagnostic data, while the lower waveform of (a) shows signal on



(a) Waveform of K-line and TX-line (b) Waveform of K-line and RX-line

Fig. 6. Waveforms of diagnostic operations

TX(transmit) line from mobile handsets to the converting board. After connection establishment, the application program on mobile handsets generates signal for keeping connection periodically as shown in the lower waveform according to the protocol and the command from the remote server.

Although the response of the ECU is sent back from the converting board to mobile handsets though RX(receive) line as shown in the waveform of (b), to remove unnecessary data exchange on wireless networks, it is discarded according to the protocol and the command from the remote server.

6 Conclusion

In this paper, we propose a diagnostic protocol and system for U-car with mobile handsets, which has same functionality of conventional scanners, automobile diagnostic instruments. Since diagnostic algorithms are located on the remote server, we can construct cost-effective vehicle diagnostic systems.

Experimental work shows the validity of the proposed protocol and system. Although the proposed system is constructed based on mobile handsets, it can be easily extended to car-PCs and other systems for U-car.

Further works can be done in two ways. One is for applying the proposed scheme to other systems for U-car which has cost-effective network capability than mobile handsets. The other is for elimination of wired connection between mobile handsets and the converting board by using wireless PAN(Personal Area Network) technologies.

Acknowledgment

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